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AT URBANA-CHAMPAIGN

Evaluation of Conservation Performance in Cropland Regions of the United States Using Process-Based Models

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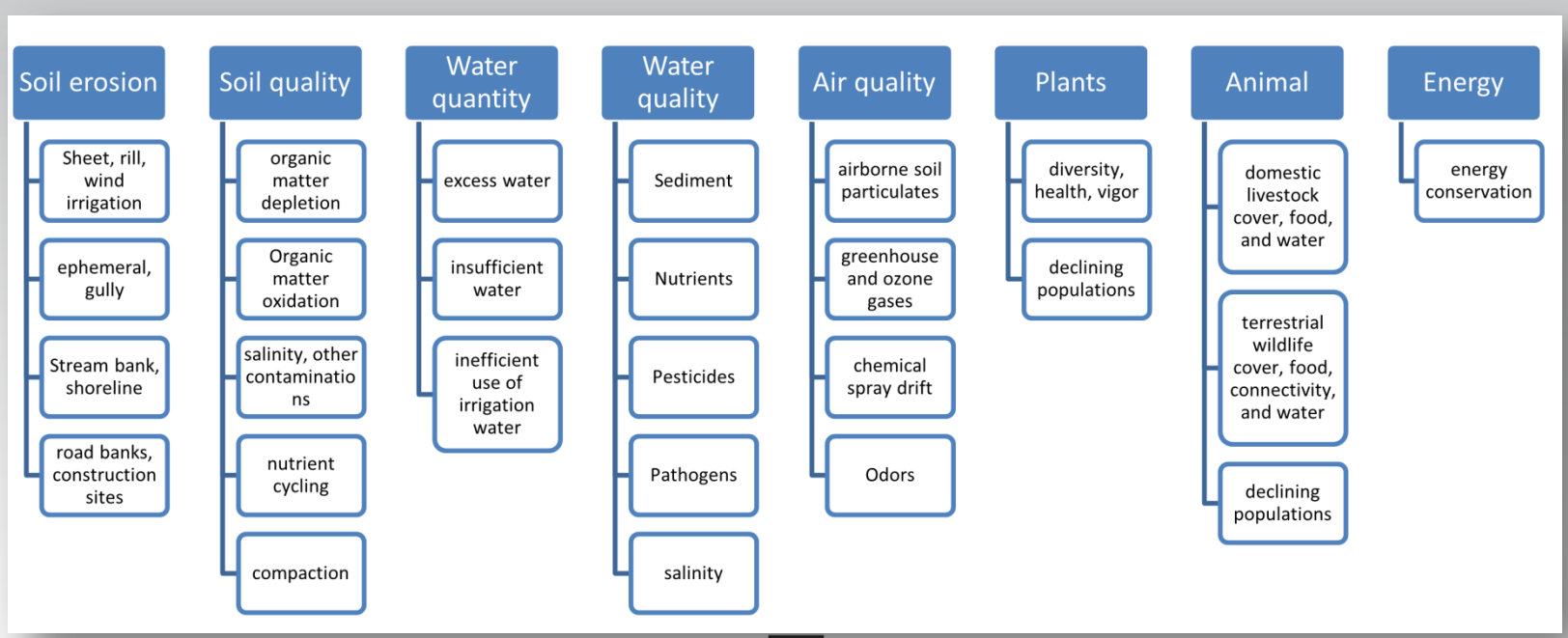
Conservation Stewardship Program (CSP)

- A comprehensive conservation program of USDA-NRCS
  - ✓ Address particular resource concerns related to various ecosystem services provided by a given farm management practice
  - ✓ Encourage producers to manage, maintain, and expand conservation activities on their lands by rewarding payments to them
- Application procedures
  - ✓ Verify program eligibility and submit an application form to local NRCS
  - ✓ Score the applicant's current and planned conservation practices using **Conservation Measurement Tool (CMT)**
  - ✓ Determine the payments that the producer will receive if the applicant ranks for funding

Conservation Measurement Tool (CMT)

- A tool to evaluate conservation performance by ranking management practices according to their influence on specific resource concerns
  - ✓ 8 macro-resource concerns & 27 micro-resource concerns



Cropland Existing Activity Conservation Performance

macro-concern

micro-concerns

scores

		Soil Erosion Concerns			
		sheet, rill, wind, irrigation,	ephemeral, gully	streambank, shoreline*	road banks, construction sites*
1	**Enter the length of your rotation in "years" .**				
2	**Based on your rotation**, **enter the number of your harvested crops that are included in each residue category (a-e).** These questions have crops grouped based on residue quality and quantity. Do not include cover crops in your responses.				
	a) Enter the number of years in your rotation that include the following conditions: bare fallow crop periods (both chemical and tilled fallow), idle bare fields, or harvested sod.	-5	-5	0	0
	b) Enter the number of harvested crops in your rotation that are included in the list below or included in the comments (or are similar to those listed if not listed): Asparagus, Beans dry edible, Beets, Broccoli, Cabbage, Carrots, Strawberries, Vegetables, or similar crops.	-3	-3	0	0
	c) Enter the number of harvested crops in your rotation that are included in the list below (or are similar to the list below if not listed): Buckwheat, Canola, Chicory, Coffee, Corn silage, Cotton, Flaxseed, Guar, Hops, Lentils, Peanuts, Pineapples, Potatoes, Safflower, Soybeans, Sugarbeets, Sunflower, Tobacco, or similar crops (see list).	0	0	0	0
	d) Enter the number of harvested crops in your rotation that are included in the list below (or are similar to the list below if not listed): Amaranth, Berry/Fruit Crops (Trees and Shrubs), Corn Grain/Popcorn, Cranberries, Mint all for oil, Mushrooms, Nut Trees, Rapeseed, Rice, Small Grains, Sorghum all, Sugarcane, or similar crops (see list).	3	3	0	0
	e) Enter the number of harvested crops in your rotation that are included in the list below (or are similar to the list below if not listed): Dichondra, Grass Hay/Seed, Legume Hay /Seed, Lotus root, or similar herbaceous perennial crops.	5	5	0	0

Improvement of the CMT needed?

- Like other expert systems relied on expert judgment and available technical information, some factors are simplified while others are emphasized
  - ✓ Are including local information (e.g. local soil and climatic characteristics) better?
  - ✓ Are weights correct?

Questions, enhancements, and conservation practices	**Soil Erosion Concerns** sheet, rill, wind, irrigation	**Soil Quality Functions** organic matter depletion (habitat, compaction, water partitioning)
	Score	Score
Residue management practices	3	3
Contouring	2	1
Strip cropping	2	2
Terraces	1	0
Contour buffer strips	3	3

Objective

- Develop an evaluation framework to investigate the performance of the CMT in US cropland regions by utilizing process-based models
  - ✓ Generate county-specific scenarios for key conservation practices related to proxies for ***soil erosion and soil quality resources concerns*** that considered by CMT
  - ✓ Simulate these scenarios using RUSLE2 for soil erosion rate, the soil conditioning index and surrogate CENTURY for soil C sequestration rates
  - ✓ Analyze the influence of regions and practices on model predictions

Process-based Model

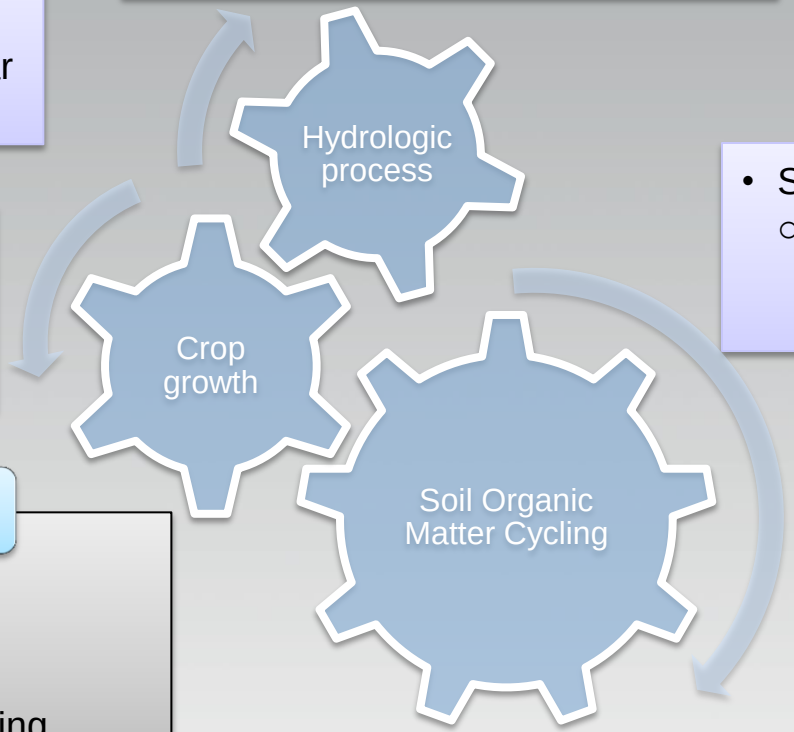
- A representation of a real system through the use of mathematical questions or relationships
- Widely employed by agronomist and environmental scientists
  - Improve our understanding of biogeochemical processes
  - Test hypothetical scenarios of farm management practices
  - Analyze future responses of agro-ecosystems to climate changes
- Integrate three distinct categories of sub-modules
  - Crop growth, hydrology, and soil organic matter cycling

Hydrology

- Evapotranspiration
- Runoff
- Drainage and irrigation

- Climate data
  - Precipitation, temperature, and solar radiation

- Nutrient leaching



- Soil characteristics
  - Texture, water holding capacity, and saturated hydrologic conductivity

- Crop yields
- Agronomic indices (harvest index and root to shoot ratio)

Crop growth

- Phenology
- Leaf area dynamics
- Radiation interception
- C and nutrient partitioning

- Soil C sequestration
- Greenhouse gas emissions

- Management options
  - Crop cultivar, planting date and density, fertilizer application rate, and tillage

Soil organic matter (SOM) cycling

- SOM decomposition
- Allocation of C and nutrients to SOM pools

Evaluation Framework

1. ***Select process-based models to generate model's predictions varied with specific field conditions***

- Model's predictions can be related to soil erosion and soil quality macro-concerns
- RUSLE2 (Revised Universal Soil Loss Equation 2)
  - ✓ Estimate *water erosion rates (Mg soil lost ha^{-1} yr^{-1})* and *soil conditioning index (SCI)*
- Surrogate CENTURY
  - ✓ Predict *soil C sequestration rate (Mg C ha^{-1} yr^{-1})*

RUSLE2

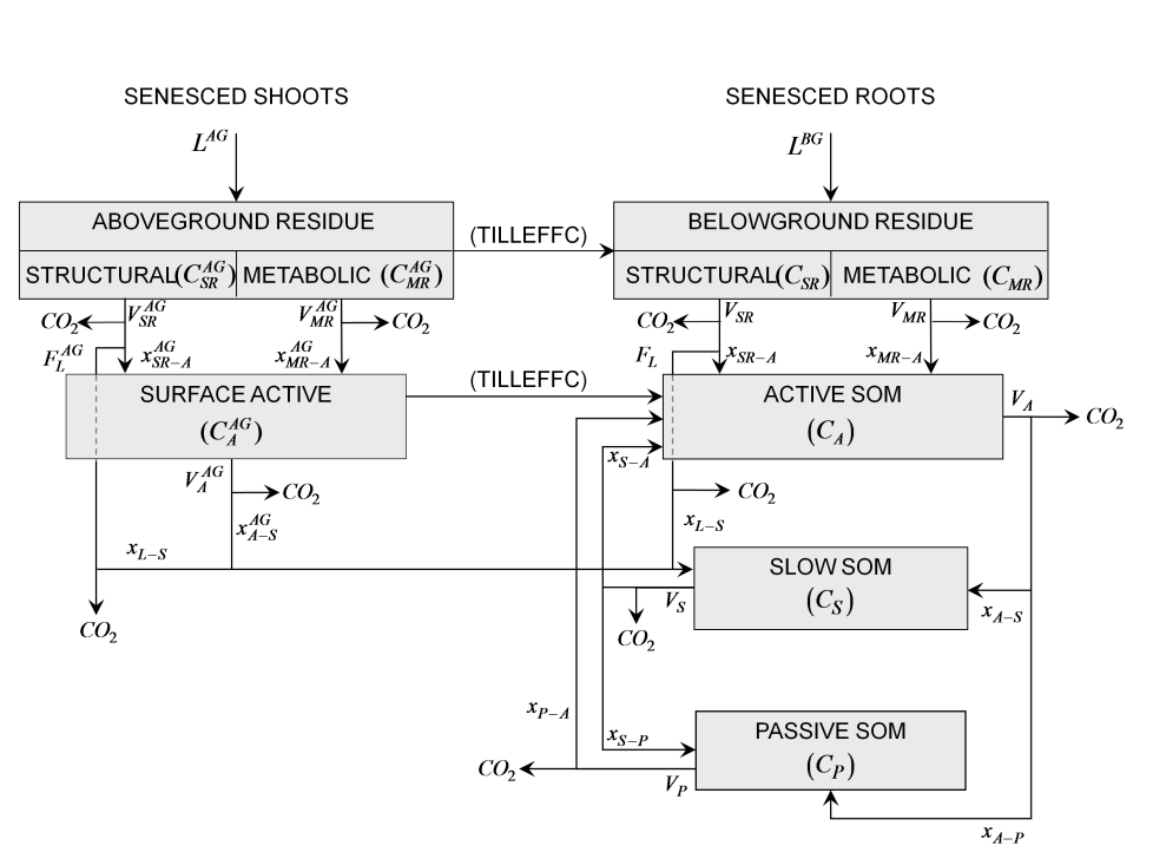
- Predict soil erosion using information about topography, weather, soil type, soil cover management, and soil erosion reducing practices
- Also calculate soil conditioning index (SCI)
  - ✓ Expresses the effects of the system on organic matter trends as a primary indicator of soil condition
  - ✓ Provides a means to evaluate and design conservation systems that maintain or improve soil condition

$$SCI = (OM \cdot 0.4) + (FO \cdot 0.4) + (ER \cdot 0.4)$$

  - ✓ OM accounts for organic material returned to the soil, FO represents field operation effects, ER is the sorting and removal of surface soil material by sheet, rill and/or wind erosion

CENTURY soil organic matter model

- Applied across wide biogeographical ranges and spatial scales
- Adapt multiple “pool” structure to model soil C changes as a function of land use history, weather, soil texture, and management practices



Surrogate CENTURY

- Mass balance and decomposition kinetics equations for CENTURY's pools and C flows are coded and solved using the PROC MODEL of SAS
  - ✓ Efficiently run simultaneous CENTURY simulations for various scenarios
- Important differences are
  - ✓ Decoupled from models of plant growth, nutrient cycling, and hydrologic processes described within the CENTURY and variants
  - ✓ Capable of accounting for soil erosion and compaction

2. Select key conservation practices modeled

Questions, enhancements, and conservation practices	Definition
Residue management practices (no tillage)	Soil and residue is left undisturbed from harvest to planting except for nutrient injection. Planting, drilling or nutrient application is done in a narrow seedbed or slot created by coulters, row cleaners, or disk openers. No full-width tillage operations are done
Contouring	A practice preparing the soil, planting and cultivating crops around a hill rather than up and down the hill. Contour rows run around a slope nearly n the level. The rows form hundreds of small dams to slow runoff
Strip cropping	A system of growing crops in approximately even width strips or bands on the contour to reduce soil erosion. The crops are arranged so that a strip of meadow or close growing crop is alternated with a strip of row crop
Terraces	Terraces are earthen structures that intercept runoff on moderate to steep slopes. They transform long slopes into a series of shorter slopes. Terraces reduce the rate of runoff and allow soil particles to settle out. The resulting cleaner water is then carried off the field in a non-erosive manner.
Contour buffer strips	Strips of perennial vegetation alternated down the slope with wider cultivated strips that are farmed on the contour. Contour buffers strips are usually narrower than the cultivated strips. Vegetation in strips consists of adapted species of grasses or a mixture of grasses and legumes.

3. Develop county-specific scenarios with or without conservation practices

- ✓ Scenarios represent dominant soil type and crop rotation at 60 selected counties
- ✓ Utilize national statistics and remote sensing databases

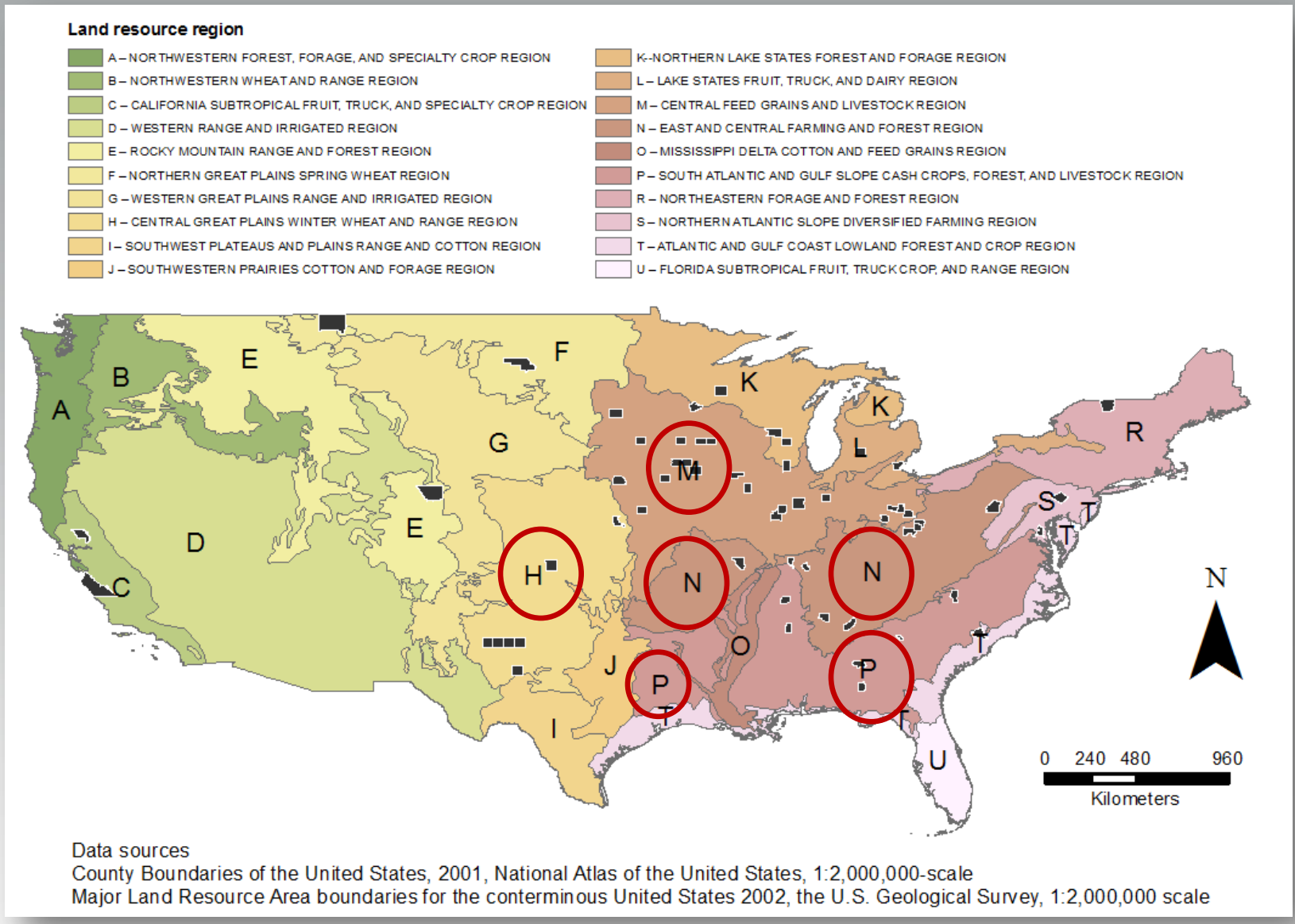
Land resource region	State	County	Crop rotation	Dominant soil type
M	Iowa	Muscatine	corn-soybean	Walford silt loam, 0 to 2 percent slopes
M	Iowa	O'Brien	corn-soybean	Galva silty clay loam, 2 to 5 percent slopes
M	Iowa	Story	corn-soybean	Clarion loam, 2 to 5 % slopes
M	Kansas	Brown	corn-soybean	Wymore silty clay loam, 3 to 6 % slopes
M	Minnesota	Dakota	corn-soybean	Waukegan silt loam, 0 to 1 % slopes
M	Nebraska	Saunders	corn-soybean	Yutan, eroded-Judson complex, 6 to 11 % slopes

4. Run scenarios

- RUSLE2 model runs
  - ✓ Use NRCS national RUSLE2 databases of climate, soil, topography, and land use
- Surrogate CENTURY model runs
  - ✓ Reconstruct farming management history prior to the present [pristine (before 1880), early-agricultural (1880-1950), modern-agricultural (1951-2010), and projected period (2011-2015)]
  - ✓ Estimate C input rates to soil by using historical records of crop yields and agronomic indices
  - ✓ Estimate weather effects on soil C decay from monthly temperature and precipitation
  - ✓ Account for soil C loss due to soil erosion

5. Analyze model's predictions

- Soil erosion rates, SCI, and soil C sequestration rates modeled were sorted by Land Resource Region (LRRs) to expedite a statistical analysis
  - ✓ LRR: a geographical area aggregated by particular patterns of soils, geology, climate, water resources, and land use
- Statistically analyze the rates from conservation practices by 4 LRRs
  - ✓ P (South Atlantic and gulf slope cash crops, forest, and livestock region), H (Central great plains winter wheat and range region), M (Central feed grains and livestock region), and N (East and central farming and forest region)



Data sources
County Boundaries of the United States, 2001, National Atlas of the United States, 1:2,000,000-scale
Major Land Resource Area boundaries for the conterminous United States 2002, the U.S. Geological Survey, 1:2,000,000 scale

ANOVA on modeled soil erosion rate

- Significant effects of LRR and practices on soil erosion
- No significant effect of interaction between the two

LRR	H (KS, TX)	M (IL, IN, IA, KS, MN, NE, SD, WI)	N (AL, KY, OH, PA)	P (AL, GA, MS, NC, TN)
# counties studied	8	21	11	6
Mean rate (Mg soil lost ha^{-1} yr^{-1})	1.87	2.78	3.41	8.85
Mean comparison	A	A	A	B

Practice	No tillage	Contouring	Terrace	Buffer strip	Strip cropping	Conventional tillage
Mean rate (Mg soil lost ha^{-1} yr^{-1})	1.77	3.02	4.45	4.52	5.25	6.36
Mean comparison	A	AB	AC	AD	BD	CD

ANOVA on modeled SCI

- Significant effects of LRR and practices on soil erosion
- No significant effect of interaction between the two

LRR	H (KS, TX)	M (IL, IN, IA, KS, MN, NE, SD, WI)	N (AL, KY, OH, PA)	P (AL, GA, MS, NC, TN)
# counties studied	8	21	11	6
Mean (unitless)	-0.11	0.24	-0.07	-0.65
Mean comparison	B	C	B	A

Practice	No tillage	Contouring	Terrace	Buffer strip	Strip cropping	Conventional tillage
Mean (unitless)	0.38	-0.12	-0.23	-0.24	-0.29	-0.38
Mean comparison	B	A	A	A	A	A

ANOVA on modeled soil C sequestration

- Significant effects of LRR and practices on soil erosion
- No significant effect of interaction between the two

LRR	H (KS, TX)	M (IL, IN, IA, KS, MN, NE, SD, WI)	N (AL, KY, OH, PA)	P (AL, GA, MS, NC, TN)
# counties studied	8	21	11	6
Mean rate (Mg soil C ha^{-1} yr^{-1})	-0.02	0.03	0.01	-0.03
Mean comparison	A	B	AB	A

Practice	No tillage	Contouring	Terrace	Buffer strip	Strip cropping	Conventional tillage
Mean rate (Mg soil lost ha^{-1} yr^{-1})	0.12	-0.02	-0.02	-0.02	-0.02	-0.03
Mean comparison	B	A	A	A	A	A

Comparison CMT rank with modeled rank

	Soil erosion concerns			Soil quality concern		
	CMT rank	Normalized erosion score		CMT rank	Normalized SCI score	Normalized C sequestration score
No tillage	3	3.0		3	3.0	3.0
Contouring	2	2.2		1	1.0	0.2
Terrace	1	1.2		0	0.6	0.2
Buffer strip	3	1.2		3	0.6	0.2
Strip cropping	2	0.7		2	0.4	0.2

- Normalized score
  - ✓ Relative score compared to maximum CMT score among conservation practices (i.e. no tillage)

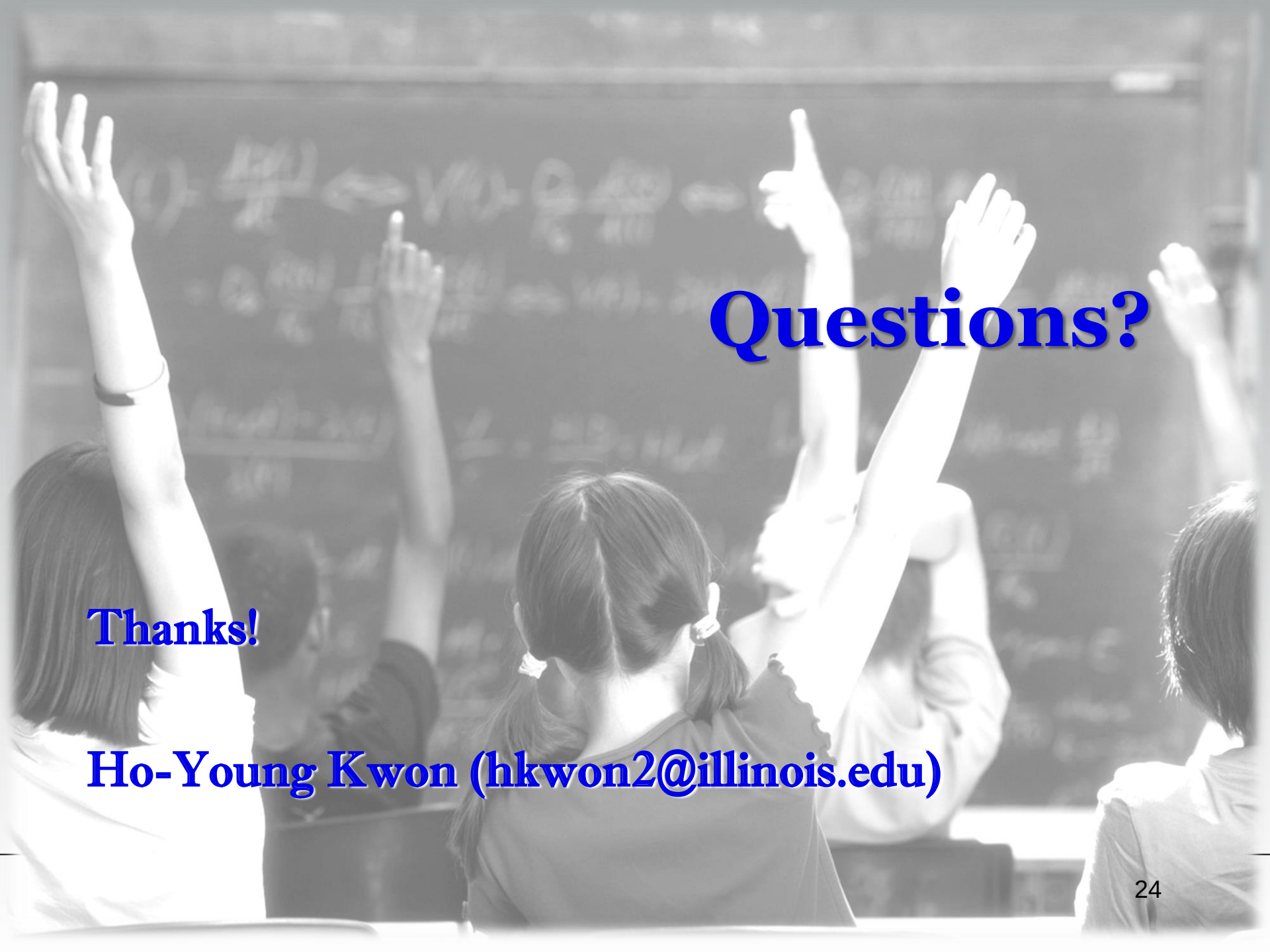
Summary

- The RUSLE2 predicted
  - ✓ Higher erosion rates for LRR P (South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock Region) than H (Central Great Plains Winter Wheat and Range), M (Central Feed Grains and Livestock), N (East and Central Farming and Forest Regions)
  - ✓ Lower erosion rates for no tillage practice than other practices
- The RUSLE2 and CENTURY predicted
  - ✓ Higher SCI and soil C sequestration rates for M than P, H, and N
  - ✓ Higher SCI and soil C sequestration rates for no tillage practice than other practices
- CMT scoring might be improved by higher weighting on residue management and regionalizing weighting

Further studies

- Investigate other LRR whether our conclusion could be applied to other regions

- Develop strategies and modeling frameworks akin to the one outlined here to permit the agency to estimate the effects of precision conservation that are currently rewarded by CMT



Questions?

Thanks!

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